Appendix V.

Channel Monitoring Methods

CHANNEL GEOMORPHOLOGY MONITORING METHODS

PHASES 2 AND 3 OF THE LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT

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INTRODUCTION

The monitoring component of a functional adaptive management program requires field monitoring, data compilation and analysis, and interpretation of results in order to improve designs and implementation. This appendix provides a detailed description of the methods required to complete the field monitoring tasks for Phases 2 through 4 of the Ecological Monitoring Plan for the Lower Clear Creek Floodway Rehabilitation Project. It is intended to provide enough detailed discussion and description of technique so that monitoring personnel can use it as a guide for developing field monitoring programs to satisfy the Fisheries Resources and Geomorphology monitoring objectives. These objectives are described in the Ecological Monitoring Plan and the reader should be familiar with them.

Please note that many of the methods and techniques presented in this appendix are also presented in the U. S. Forest Service General Technical Report RM-245, *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al. 1994). This guide is periodically referenced herein as RM-245. Monitoring personnel are encouraged to obtain and read RM-245 as many of the following topics are discussed in greater detail than presented in this appendix. In addition, other fundamental techniques not discussed in this appendix are presented in RM-245 that may prove beneficial for monitoring personnel (e.g., surveying, measuring discharge, characterizing bed and bank material). Copies of RM-245 can be obtained From the U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526.

In addition to describing monitoring procedures for Clear Creek, this appendix provides materials lists to complete the installation of monitoring stations. Most of the materials that are listed can be purchased at a conventional hardware store, however others (e.g., aluminum tags, field notebooks, surveying gear) must be purchased from survey supply houses. One such supply house is Forestry Suppliers, Inc., a company specializing in tools, instruments, and equipment for natural resource sciences. Where applicable, the Forestry Suppliers catalog number will follow an item in parentheses, for example: (FS #49217). Forestry Suppliers usually offers several brands or types of the same general item; the catalog number provided is merely an example of the type of equipment recommended for the monitoring task. Forestry Suppliers, Inc. can be contacted at (800) 360-7788, or via the Internet at: http://www.forestry-suppliers.com.

MONITORING METHODS

1.0 FIELD NOTEBOOKS

A field notebook may very well be the most important piece of equipment used for any project. Most, if not all site observations, sketches, and measurements will be recorded in the field notebook. As described in RM-245, most hydrologists use bound field notebooks that are about 5” x 7”, with alternate graph pages, ledger pages, and various tables and equations at the back for reference. Laid flat, they photocopy onto standard 8 ½” x 11” sheets for standard filing. Each field book should be assigned its own unique number (e.g., Clear Creek Monitoring Field book No. 1). If field notebooks contain weatherproof paper, (e.g., “Rite in the Rain” brand (FS #49326)), then a harder #4 lead pencil is recommended as #2 lead tends to smudge on weatherproof paper.

Field notes should always be written clearly and legibly. It is likely that numerous field personnel will use the same notebook before it is completely filled, therefore, it is imperative that all notes and sketches be written with the intent that others will need to interpret them (possibly years in the future). Always begin notes for a new site visit on a fresh page, and include the names of all field crew members, date, time, and weather conditions. All notes and sketches should be made dark enough so that they photocopy well, and should always be written in pencil. Notes should never be erased (particularly survey notes); they should be lined out and any corrections should be noted and initialed.

Clearly label the inside front cover or first page of the field notebook with a name, address, and phone number in case the book is lost. Including a written offer for a reward is also a good idea. Leave the first two or three pages blank to list the book’s contents and any other special notes (e.g., symbols, abbreviations, etc.). After returning to the office from the field, always photocopy the day’s field notes and archive them in an off-site location (in case of fire, theft, or some other unfortunate catastrophe). When finished, store all field notebooks in the office so they are available for reference and for the next field session.

2.0 AERIAL PHOTOGRAPHS

Aerial photographs provide a planform view of project sites and serve as a basis for documenting changes in site conditions over time. Careful analysis of the aerial photos can be used to interpret changes in channel location, channel morphology, vegetation, or other variables.

Monitoring

Aerial photographs should be flown after construction to document as-built conditions at both the project site and Reading Bar borrow site. While there can not be a set rule for the frequency of taking aerial photographs, we suggest they be re-taken as each phase of the restoration project is completed, every three years, or after a high flow that causes dramatic changes to channel morphology, whichever is sooner. All aerial photos should be taken at a 1” = 350’ (1:4,200) scale, because this scale provides excellent visibility of the floodway, excellent image quality of enlargements (scale can be increased by 10x to 1” = 35’ without losing much photographic resolution), and is consistency with previous aerial photo scale.

Stereoscopic aerial photos are those that can be overlapped and viewed through a stereoscope, which renders a three-dimensional image by adding topographic relief to the viewer's field of vision. This technique is very useful in interpreting landforms and other features that can otherwise be indistinguishable, especially at sites such as river channels and floodplains that have little topographic relief. Because individual aerial photographs must be overlapped to view in stereo, the total number of photos taken to cover one site is greater than non-stereo coverage (and therefore cost more). However, the resolution offered by stereo pairs, particularly along a channel and over a floodplain, is superior to non-stereo coverage, and allows the photos to be orthorectified if desired. In addition, color aerial photos will provide further resolution to a site and aid in interpreting certain features that may appear different in black-and-white.

Based on June, 2001 price estimates from Hedges Aerial Surveys of Redding, CA (the same contractor who provided 1997 and 2000 photo coverage for the Clear Creek project), the cost for various types of aerial photographic coverage is presented in the following table:

	Non-stereo black and white	Non-stereo color	Stereo black and white	Stereo color
1”=350’ scale prints of restoration project only	$900	$1,300	$1,000	$1,500
1”=350’ scale prints from Sacramento River to Clear Creek Bridge	$1,200	$1,500	$1,800	$2,300
1”=350’ scale prints from Sacramento River to Whiskeytown Dam	$1,700	$2,750	$3,400	$5,500

The above listed costs are provided for budget purposes only, and the actual cost may vary.

A conventional aerial photograph contains image displacements caused by the tilting of the camera and the terrain relief. The stated scale is approximate and is not uniform across the photo; therefore, measurements made from the photograph may not be accurate. Orthorectification is a process that corrects photo distortion. Once an aerial photograph has been orthorectified, it becomes a photographic map that contains a uniform scale across the photo. The 1997 digitally orthorectified photos produced by ENPLAN has served as the base map photo for the work done on lower Clear Creek. At minimum, we recommend that color stereo pairs be taken from the Sacramento River to Clear Creek bridge, but not be orthorectified due to significant cost. We also recommend that once all construction activities and revegetation are completed, that the next photo set be digitally orthorectified to serve as the next base map (replacing the 1997 photo base map).

3.0 PHOTO POINT MONITORING

Photomonitoring is the process of taking landscape or feature photographs repeatedly over time from the same location (i.e., the photopoint), perspective, and frame so that differences between years can be compared (Elzinga et al. 1998). In general, a photomonitoring program consists of: selecting, and installing photopoints; developing a standardized protocol for photopoint relocation and photography; taking photographs at all photopoints and taking standardized notes, and; documenting and archiving all photographs taken during photomonitoring.

Materials

Quality and consistent photomonitoring equipment are the basis of good, standardized photographs. The pieces of equipment used for a photomonitoring program include:

- camera, shutter release cable, tripod
- hand pruners, machete, and pruning saw for clearing vegetation
- blank photomonitoring data sheets, to be filled out after every photograph
- photomonitoring fieldbook, with photopoint location descriptions
- scale pole marked in 0.5 ft increments (FS #40046)
- plumb bob (or fishing weights and line for constructing a plumb bob)
- chalk board and chalk for writing relevant photopoint data
- flagging tape to mark photopoint location (FS #57905)
- compass for measuring the focal point bearing (FS #37182)
- clinometer for measuring the focal point angle (FS #43830)
- engineer’s measuring tape (in 0.01 increments) for measuring the camera height above the observation monument (FS #71175)
- two 300-ft survey tapes for triangulating observation points (FS #39532 or #39851)

The camera used for photomonitoring should either be digital or 35mm. Digital cameras are attractive choices because the photographs can be easily archived and reproduced. No matter what camera is selected for the project, it is best if the same camera is used throughout the project history and the same settings (e.g., ASA or image quality) are used for successive photographs.

Methods

A photomonitoring program must take repeated photographs from the same location. To be able to effectively compare photographs taken at the same point on different dates, the photographs must be as equivalent to each other as possible. A photomonitoring program must consider the time of year that the lighting and vegetation will be in a similar condition as the first photograph at the photopoint. In addition, photomonitoring timing must consider river discharge and plant growth. Once a photomonitoring program is developed (locations selected, monitoring schedule developed), the actual benchmark for where photographs are to be taken, or photopoints, must be selected.

The first type of photopoint consists of two rebar pins, a line of site pin, and an observation pin (Figure 3.1). Rebar pins monument both the observation point and the line of sight, and are labeled with aluminum tags. The camera and tripod are setup over the observation pin and centered over it using a plumb bob. The line of sight pin is 25 ft away along a fixed compass bearing (the compass bearing is recorded on the photopoint data sheet which is in the fieldbook). The field of view and focal point (in the cameras viewfinder), is centered on the chalkboard sitting atop the scale pole. No declination compensation (to adjust for difference in true and magnetic north) is required to the bearing recorder on the data sheet.

The second type of photopoint consists of a nail with a washer (the observation point), and a fixed point demarcating the line of sight (Figure 3.2). This photopoint type is commonly used on hillsides. The camera and tripod are setup and centered (using a plumb bob) over the nail. The field of view is determined by a compass bearing and an inclination. In some cases a line of sight monument is described in for the photopoint, in other cases no line of sight monument was used. Therefore, the field of view is centered using the line of sight monument, compass bearing and inclination.

The third type of photopoint consists of two pins from which an observation point is triangulated, and a fixed point demarcating the line of sight (Figure 3.3). This photopoint type is typically used were the observation point occurs in the river. Two 300-ft surveying tapes are attached to triangulation points (usually rebar pins), and using distances from each triangulation point the observation point is relocated and the tripod and camera are setup at this point. The field of view is determined by a compass bearing and an inclination. It is especially important to use the most recent photograph taken from that photopoint to help reestablish the same field of view as the previous monitoring. In some cases a line of sight monument is described in for the photopoint. Therefore, the field of view is centered using the line of sight monument, compass bearing and inclination.

All photopoint monuments must be photographed at the time of installation and should be GPS surveyed by the Department of Water Resources to precisely locate the photopoint on the Clear Creek base map. The monument photographs are intended to capture the monument's immediate surroundings, the monument itself, and any other relevant information that could prove useful in relocating the monument. The monument photographs are included the photomonitoring fieldbook, with other location information.

The photomonitoring fieldbook is the result of the first year's photomonitoring effort. For each site, the photomonitoring fieldbook contains photopoint location descriptions, photographs and descriptions of monuments (both line of site and observation pin), the most recent photopoint data sheets, and the most recent photograph taken from each photopoint. A sample photopoint data sheet is included on the CD that accompanies this appendix.

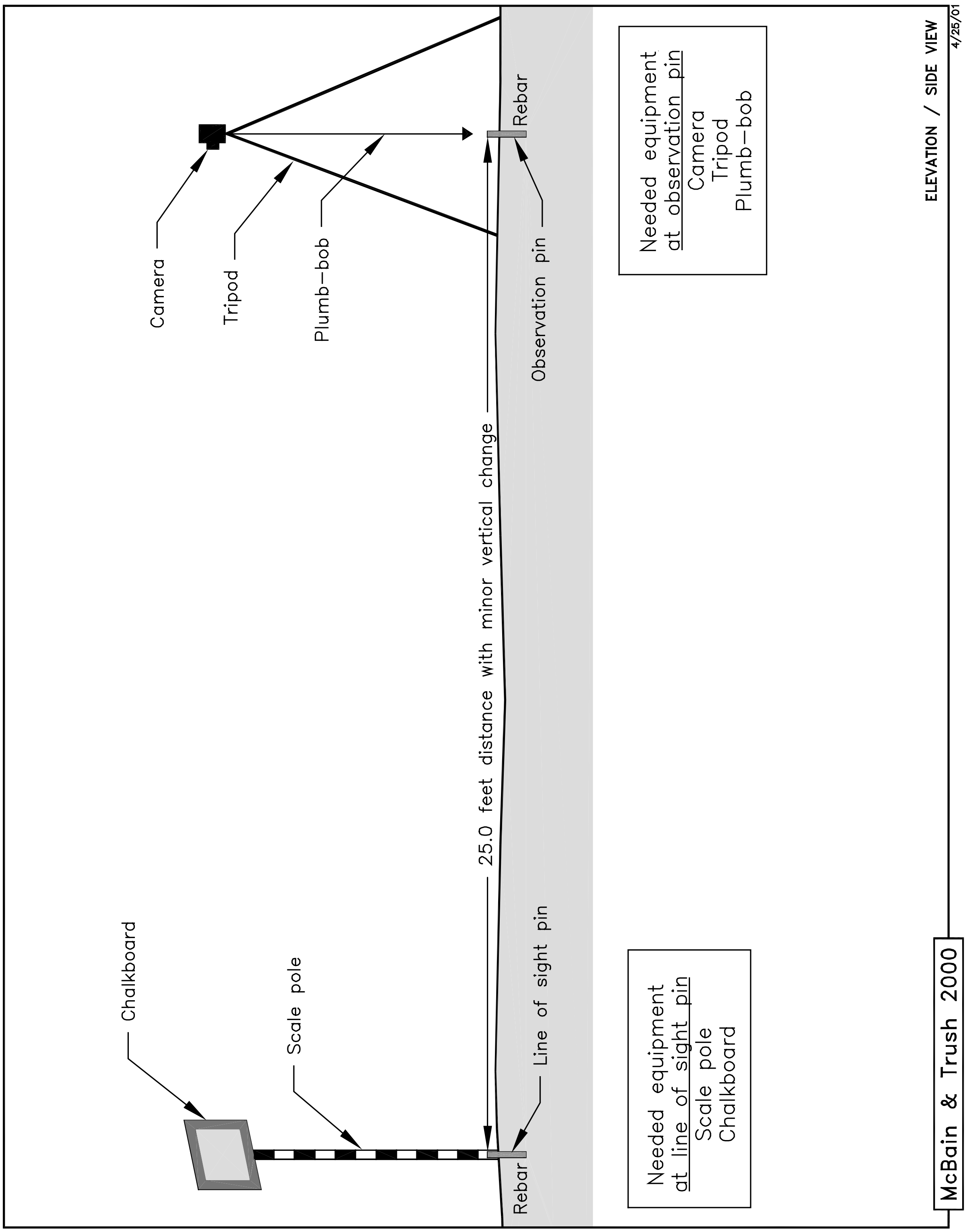

Figure 3.1: Photomonitoring point Type 1: where both observation pin and line of sight pin are established.

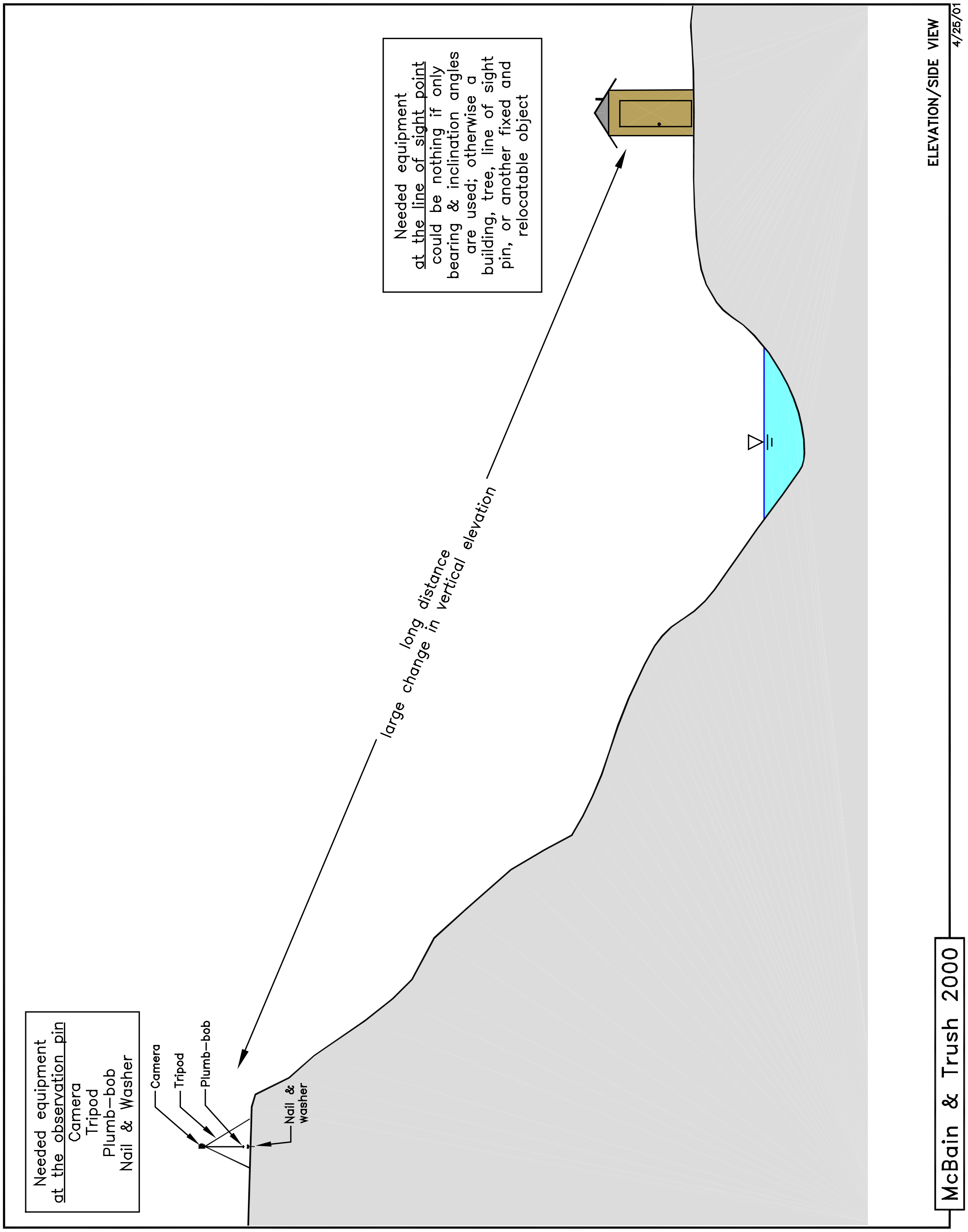

Figure 3.2: Photomonitoring point Type 2: photopoint where only the observation pin can be established.

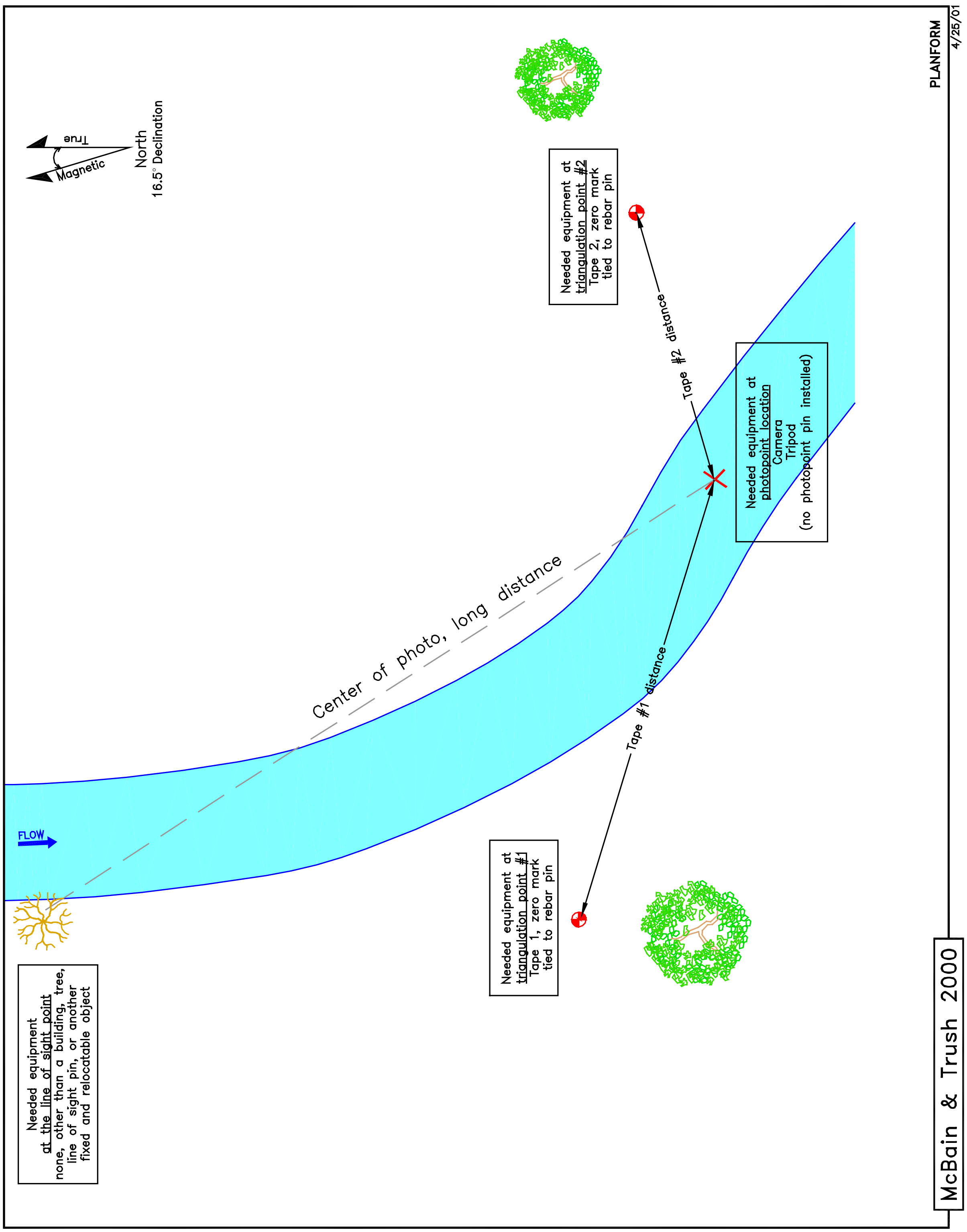

Figure 3.3: Photomonitoring point Type 3: photopoint where oberservation point monument can not be established (photopoint position triangulated from two fixed points).

Installation

The following table lists materials required to install photopoint monuments (note that this list includes materials for all three photopoint types). Where applicable, a Forestry Suppliers catalog number follows the item in parentheses.

- ½” rebar, for photopoint monuments, cut at 3’ to 5’ lengths
- 1” washers for photopoint monuments
- 12” galvanized spikes for photopoint monuments
- 1”-diameter (or similar size) aluminum tags for labeling photopoint monuments (FS #79360 or FS #79500)
- plastic tarp, to paint washers and monuments on
- wire, wire cutters and pliers for affixing the tags
- putty Epoxy, to affix monuments to bedrock or concrete if needed
- “PK” nails to for installing monuments into asphalt
- orange paint, for painting monuments (FS #57561)
- small sledge hammer for installing photopoints (FS #67244)
- stamp kit, for stamping the photopoint numbers on the tags or washers

Most of the above listed materials can be purchased at a conventional hardware store, however others (e.g., aluminum tags) can be purchased from Forestry Suppliers, Inc., a company specializing in tools, instruments, and equipment for natural resource sciences.

Monitoring

Several Photopoints may be clustered around a site, or one site may contain only a single photopoint. For each site, or where a single photopoint occurs, the specific site location is sketched in the photomonitoring program field book. After locating the photopoint monuments, the photomonitoring equipment can be set up and the photopoint (re)occupied. The camera and tripod are set directly over the observation monument at the predetermined height stated on the photopoint data sheet, and centered over the pin using a plumb-bob. The specific procedures are:

1. Using the site description and/or aerial photos, find the observation point/monument, and line of sight monument.
2. Set up the tripod over the observation point/monument.
3. Using a fishing line and lead weight plumb bob hanging from a central point on the tripod, center tripod over the observation monument.
4. Attach camera to tripod, on the chalkboard write the date, the discharge and the initials of the location where the discharge was measured, and the photopoint number.
5. Using an engineers tape (marked in increments of feet and tenths of feet) raise or lower the base of the camera such that the camera height is the specified distance above the observation monument (indicated on the photopoint data sheet).

6. Using a compass, determine the direction the camera's viewfinder will be aiming, specified as a bearing from magnetic north (indicated on the photopoint data sheet)
7. Center the camera's viewfinder on the chalkboard and scale pole or some other line of sight monument (indicated on the photopoint data sheet).
8. Using a clinometer, determine the angle that the camera's viewfinder will be tilted up or down, specified as inclination or angle
9. Using a line bubble level, check to ensure the horizon in the photograph framed in the viewfinder is level
10. Check the camera settings listed on the photopoint data sheet to ensure that the lens (wide angle or telephoto) settings are the same as the previous photo monitoring, and that the camera's image settings allow the photograph to be taken at full size, fine quality
11. Using the last photograph taken from the photopoint (included in the photomonitoring fieldbook), check to make sure the photographs are equivalent (with the exception of physical or vegetative changes), make any fine tuning adjustments necessary
12. Three photos should be taken at each photopoints to assure a quality photograph equivalent to the last monitoring (this setting is automatic if the camera has been properly checked before going into the field). Two photographs should be taken at different F-stops, bracketing the correct F stop (assure proper light balance in the photograph). One photograph should be taken at one F stop above the suggested F stop (as measured by a light meter), one photograph should be taken at the setting suggested by the light meter, and one photograph should be taken at one F stop below the suggested setting.
13. Fill out a new photopoint data sheet, noting any changes to the photopoint monuments, camera settings, physical disturbances etc.

Once photopoint monitoring begins, a database can be created. One way of creating a searchable database is through the use of accession numbers. This is accomplished by naming all photopoint monuments with a unique moniker according to river mile, site, photopoint number, and whether the pin is the observation or line of sight pin. This unique name is called the photopoint accession number and is also used as the database reference number for the photopoint. For example, the following accession number "PPT#816CC3LS" means:

PPT# = Photopoint number
816 = River mile 81.6
CC = Clear Creek
3 = third photopoint
LS = line of sight pin

The accession number can be looked up in the photomonitoring fieldbook to get specific details about the point and its location and can also be placed on an aluminum tag attached to the photopoint pin. By establishing this protocol, all photographs can be accessed by using the photopoint accession number.

4.0 CROSS SECTION INSTALLATION AND MONITORING

The monumented cross section serves as the location for measuring physical channel characteristics, such as channel form (e.g., location, grade, position), stream discharge, and particle size distributions. Because the cross section serves as the location from where hydraulic measurements and calculations are performed, its orientation is across the channel, perpendicular to the direction of flow.

Materials

The following materials are required to install monitoring cross sections at Clear Creek project sites (note that the following materials list is for a single cross section only).

- rebar: 4 pieces, 5/8”-diameter, cut at 3’ to 5’ lengths
- sledge hammer to install rebar (FS #67244)
- 1”-diameter (or similar size) aluminum tags (FS #79360)
- wire, wire cutters and pliers for affixing the tags
- stamp kit, for stamping the aluminum tags
- surveyor’s plastic rebar caps (FS #39496)

Installation

One of the primary purposes of establishing a cross section is to perform hydraulic calculations and document topographic change over time. To do this, set the rebar (often referred to as “pins”) along a transect that is perpendicular to flow. Drive each pin vertically into the ground to a depth where no more than 4” is exposed above the ground surface (for safety as well as to reduce risk of disturbance). Install at least two 5/8” rebar pins on each side of the stream, one that is 2-3 ft above the summer low flow water surface (preferably within 20 feet of the low flow water edge), and one at the base of the bluffs at the edge of the floodway. Pins are installed at the base of the bluffs so that the risk of them eroding in the future is minimal. Rebar on opposite sides of the channel should be set at similar elevations such that a tape stretched between pins is reasonably horizontal (Figure 4.1). Place a plastic surveyor’s rebar cap on each pin immediately after it is installed.

The exact location of each pin should be tied to the NAD83 California State Planes, Zone 1, US Foot coordinate system, as established by the Department of Water Resources. To locate the pins accurately, each pin should be initially surveyed with a survey-grade Global Positioning System (GPS). The elevation of all pins should reference the datum of the primary benchmark at each site (NAVD 88). Figures 4.2 and 4.3 show the location of primary benchmarks at each site. After the pins are installed, label them using the 1”-diameter aluminum tags. Tags are wire-attached to each pin, and the following information is stamped onto the tag: cross section name (based on longitudinal stationing established from the 1997 ENPLAN base map), date installed, and elevation of the top of the pin referenced to the primary site benchmark. The river location and longitudinal station from the 1997 ENPLAN base map is included as Figures 4.4 and 4.5 for the Restoration Grove project site and Reading Bar borrow site, respectively.

Monitoring

Monitoring is intended to document the changes along a transect either perpendicular to flow (cross section) or along the length of the channel (longitudinal and thalweg profile). In addition to the active channel, the technique described below also includes methods to monitor the scour channels.

All channel surveying, including new and existing cross sections, longitudinal profiles, and scour channels, should be re-surveyed on an annual basis and following high flow events capable of causing topographic (and therefore geomorphic) change. The channel cross section is measured by surveying the ground surface and channel topography along a tape stretched between the rebar pins. The following list includes the basic materials required to complete a topographic cross section survey:

- engineer's surveying level, tripod, and 25-foot stadia rod (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape (commonly 300' long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- "Rite in the Rain" brand field notebook (FS #49326)
- waders and wading boots
- hand pruners, machete, or pruning saw for clearing vegetation

The rebar pins at the base of the bluffs serve as survey endpoints. First, attach the zero end of the tape to the left bank (facing downstream) rebar pin. Stretch the tape tight and level across the channel, and attach it to the upper right bank rebar pin. Record the distance between pins.

After beginning the survey by establishing elevation from the primary benchmark, begin the cross section survey at the upper left bank rebar (station zero) by surveying both the top of the rebar pin and then the ground surface. From this point, the survey progresses along the tape by recording ground surface elevations at significant topographic (breaks-in-slope), geomorphic (particle size or vegetation changes), and hydrologic features (water surface elevations and high water marks). We do not recommend using a total station for cross section surveys as they do not provide the elevational precision of engineers levels, and this precision is needed to document subtle floodplain evolution. First-time surveys should record ground surface elevations at 2-foot intervals, then subsequent surveys can follow significant breaks caused by topographic changes, with spacing not exceeding 10 feet. Continue the survey across the channel to the right bank rebar pin. As with the left bank pin, survey both the ground surface at the base of the pin as well as the top of the pin. When finished, survey elevation of the primary benchmark to close the survey (do turning points if needed) and record closure error in the field notebook. If closure error is greater than 0.05 feet, repeat the turning point loop to locate and remove the survey error.

Next, survey the water surface slope (longitudinal profile) through the reach. Because water surface slope varies with discharge, slope should be surveyed each time the site is visited during different flows. In addition, water surface slope during peak flows can be reconstructed using debris lines or other high water indicators (also see Section 5.0). Water surface slope is measured by stretching the tape along the channel at the water's edge. Ideally, the length required to obtain a representative slope incorporates one complete riffle-pool sequence (Harrelson et al. 1994). For Clear Creek project sites, slopes should be

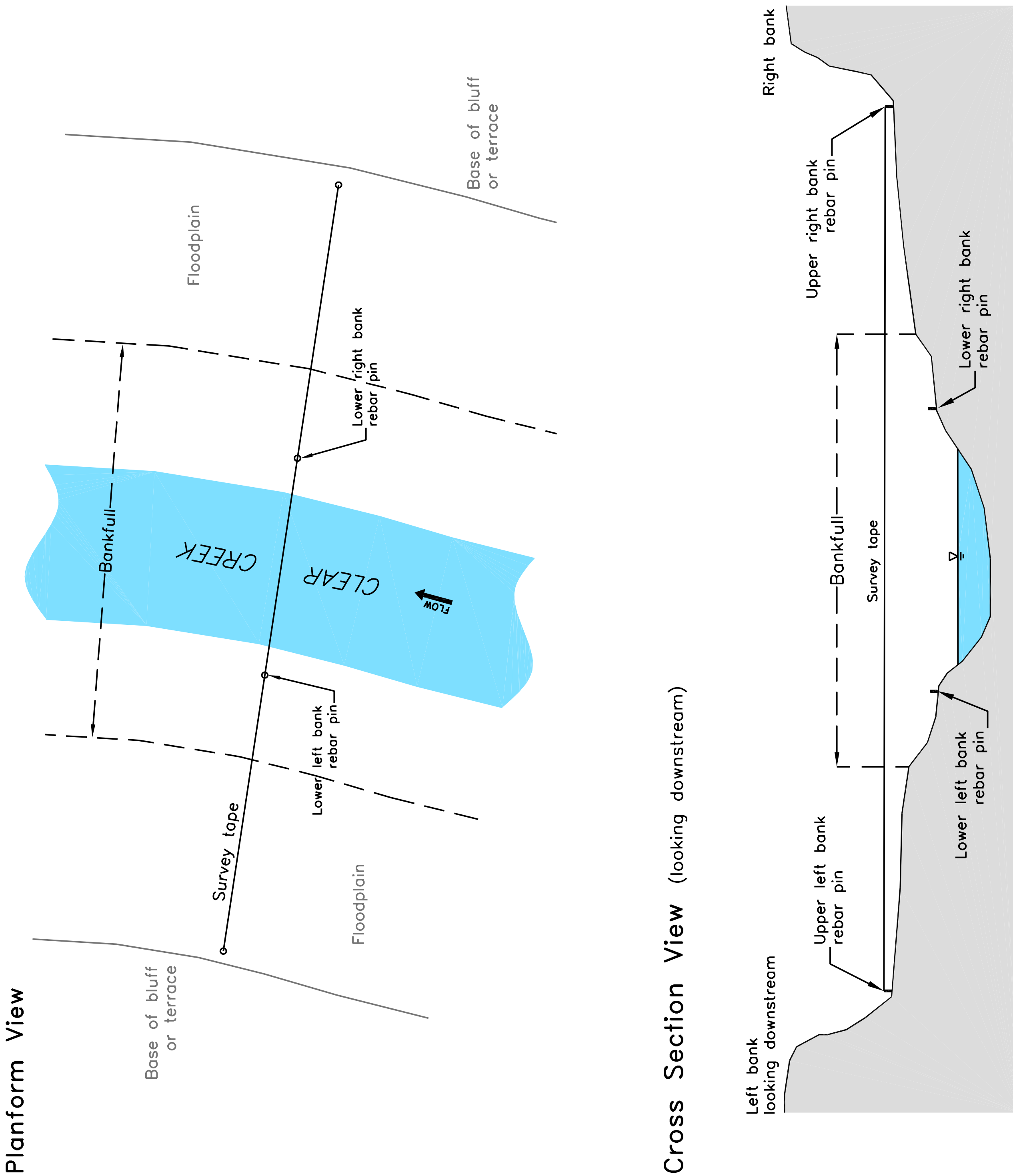

Figure 4.1: Schematic diagram of channel cross section.

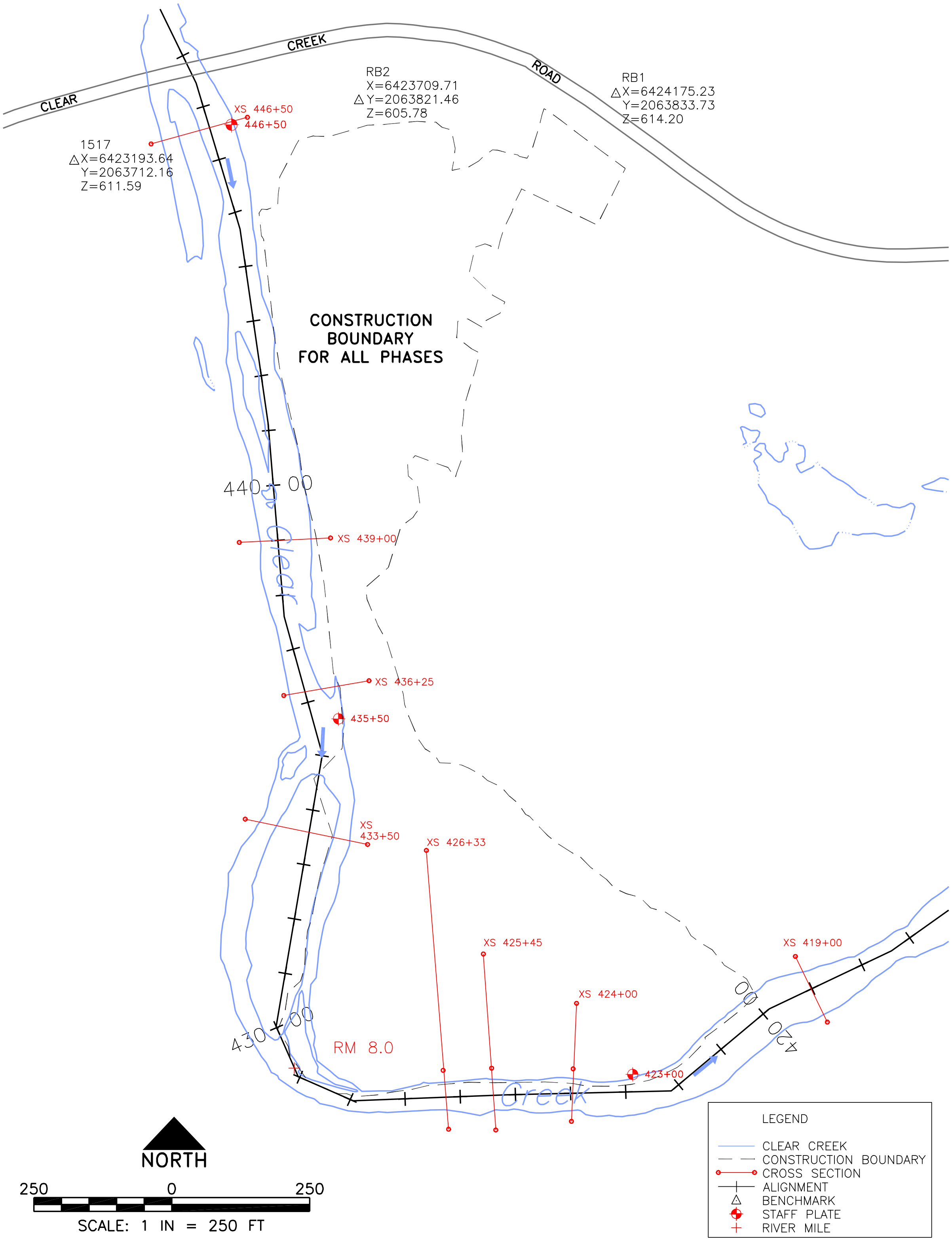

Figure 4.2: Reading Bar site map showing location and elevation of primary benchmarks, longitudinal stationing, and 1997 channel location.

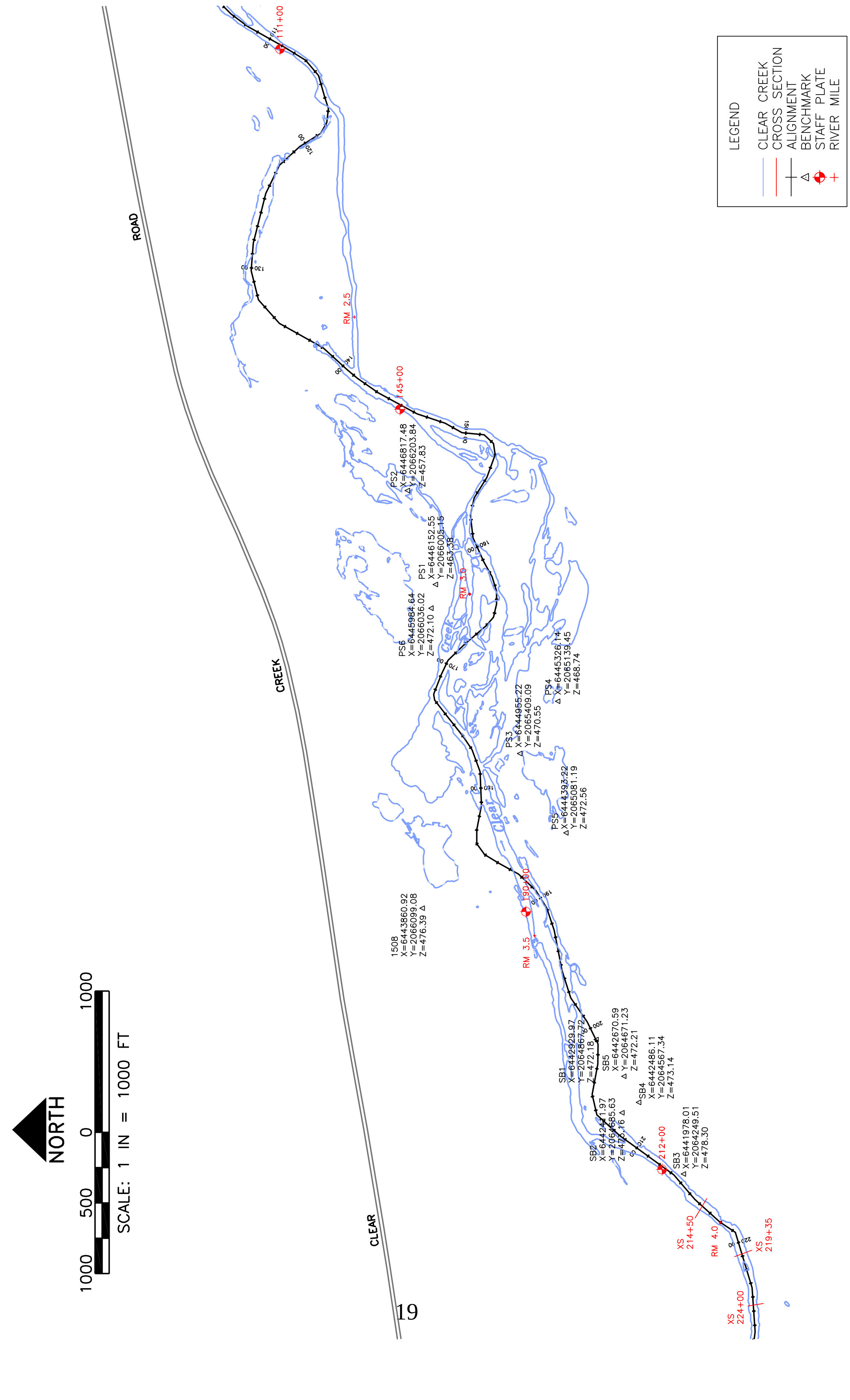

Figure 4.3: Restoration Grove site map showing location and elevation of primary benchmarks, longitudinal stationing, and 1997 channel location.

surveyed over a 300 to 400 foot length centered on the cross section (e.g., 150 feet upstream and downstream). After the tape is laid out, elevations are surveyed at approximately 20- to 50-foot intervals for the entire length of tape, concentrating on topographic changes in the water surface (i.e., breaks-in-slope) rather than equally spaced points. When the end of the tape is reached, close the survey by returning to and surveying the primary benchmark, taking turning points if needed and recording the survey error in the field notes.

After fieldwork is complete, photocopy the field notes. Then enter the survey data into an Excel workbook and plot the results. An Excel worksheet should be created for each cross section survey, such that all surveys for a given cross section are contained within a single workbook file. A survey data entry template and graphical plotting template are included with the CD that accompanies this appendix.

5.0 THALWEG PROFILE AND WATER SURFACE SURVEYS

The thalweg is the deepest portion of the channel at any given longitudinal station. Thalweg profile surveys are similar to water surface slope surveys (Section 4.0); however, in addition to surveying water surface elevations, channel topography is surveyed along its deepest portion. Similar to cross section surveys, thalweg profile surveys document the topographic changes through a given reach.

Materials

The following materials are required to conduct thalweg profile and water surface surveys at Lower Clear Creek project sites:

- Total Station (optional)
- engineer's surveying level, tripod, and 25-foot stadia rod (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape (commonly 300' long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- 5/8" rebar cut at 5-foot lengths
- sledge hammer to install rebar (FS #67244)
- "Rite in the Rain" brand field notebook (FS #49326)
- flagging (FS #57905)
- waders and wading boots
- hand pruners, machete, or pruning saw for clearing vegetation

Monitoring

Thalweg profiles are measured by surveying the channel bed surface along the deepest portion of the channel during periods of low flow. Thalweg profiles should always begin and end at the same upstream and downstream location (based on longitudinal stationing established from the 1997 ENPLAN base map). Endpoints can also be referenced to permanent features on the bank or floodplain, such as a large tree or channel cross section, provided they are spatially documented within the site coordinate system per survey-grade GPS or Total Station.

The water surface is also surveyed at the same time as the thalweg, thereby providing longitudinal channel topography and a corresponding water surface elevation with the same survey. Moreover, debris lines may be present especially following a flood event. It is important to survey these “high water mark” elevations if they are present, because they will provide water surface elevations and a slope of the flood discharge that deposited them.

To survey the thalweg and water surface, first walk the length of the channel to be surveyed and set temporary rebar vertically along the banks, beginning at the upstream end of the profile. Depending on the sinuosity of the reach, space the rebar at intervals so that a tape strung between rebar remains along the channel (slightly less than 300 ft if a 300 ft survey tape is used). Install each piece of rebar so that at least one foot is exposed above the water surface, and tie flagging to the rebar so it doesn’t produce a boating hazard during the survey. The length of channel to be surveyed should extend through the particular study reach. Next, affix the zero end of the tape to the upstream channel rebar (upstream endpoint) and connect the tape to the next downstream rebar.

After beginning the survey by establishing elevation from the primary benchmark, begin surveying the thalweg and water surface at the upstream endpoint. If using a level, assume a longitudinal station of “zero” at this point, with stationing increasing in the downstream direction. Again if using a level, survey the thalweg elevation, and document the water depth at the thalweg elevation to get the water surface elevation (thalweg elevation + water depth = water surface elevation). Water surface elevations are easiest to survey at the water’s edge if using a total station, rather than trying to survey this surface at the thalweg. Continue downstream along the tape, carefully surveying important topographic features such as the boundaries of riffles and pools. Surveying should focus on the topographic features that define the reach and how these features change with time and/or discharge; therefore, survey points should not be spaced at even intervals. When the last rebar is reached, close the survey by returning to and surveying the elevation of the primary benchmark. Record closure error in the field notebook. If closure error is greater than 0.05 feet, repeat the turning point loop to remove the error. Finally, remove the temporary rebar used to string the tape.

As mentioned above, a total station is an alternative to the level surveying method. In contrast to an engineer’s surveying level, total station surveys topographic data electronically in three dimensions with respect to the established site coordinate system. Data can therefore be plotted on a planform map and are very illustrated. The total station data logger records coordinates and elevations as individual topographic points are surveyed. Because of this, total station surveys are recommended for the thalweg profile surveys because precision is not as important as the cross section surveys, the thalweg surveys can be performed faster with a total station than an engineer’s surveying level, and thalweg location changes can be shown on a map.

Although water surface slopes can be surveyed under most flow conditions, thalweg profiles should only be surveyed during low flows when the channel is safe to wade and the flow is generally clear enough to see the channel bed. Profiles should be re-surveyed on an annual basis, and if possible, following high flow events capable of causing topographic (geomorphic) change. Keep in mind that flood debris should be present following a high flow event and this slope should be surveyed as well.

As with the cross sections, thalweg and water surface profile surveys should be transferred upon returning to the office. Photocopy the field notes and then transfer the survey data to a computer and plot the results. An Excel workbook should be created for each given profile such that the results of each field survey is contained on a worksheet within that workbook.

If a total station is used rather than an engineers level, then the "distance and elevation" data should be exported into an ASCII file that can be imported by Excel. The cross section survey data entry template and graphical plotting template on the attached CD can also be used for the thalweg profiles.

6.0 PIEZOMETERS

A piezometer is a small-diameter well constructed to measure the height of groundwater. Piezometer design for Clear Creek project sites consists of a PVC pipe that is set vertically into the ground that allows water to flow into the lower portion of the casing through a well screen. "Piezometer" and "well" are used interchangeably in this section.

Materials

The following materials are required to construct a piezometer for floodplain groundwater monitoring at lower Clear Creek monitoring sites:

- backhoe
- solid casing: 2"-diameter schedule 40 PVC pipe, threaded to accept well screen and cap
- well screen: 2"-diameter schedule 40 PVC pipe, factory slotted at 0.01" or 0.02" openings, threaded to accept solid casing and plug
- breathable cap for the top of the casing (to prevent rain or foreign materials from entering the well), and a plug for the bottom
- a pump or hand bailer to "develop" the well
- survey equipment (engineer's level, tripod, stadia rod, field notebook) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- 3 clear glass jars (4oz. or larger)
- a roll of string
- plastic 5-gallon bucket
- "Rite in the Rain" brand field notebook (FS #49326)

The piezometer materials (casing, screen, cap, plug, and bailers) can be purchased from manufacturers specializing in groundwater development and sampling products, such as Boart-Longyear. Boart-Longyear can be contacted at (800) 241-9468 or via the Internet at: http://www.boartlongyear.com/usregion/.

Because of the simple piezometer design proposed for this project, piezometers should be located in areas that are not subjected to ponding surface water as this water can infiltrate vertically and give a false water table elevation. If this setting cannot be avoided, an impervious material (e.g., bentonite or concrete grout) should be backfilled around the uppermost few feet of the well casing. The reader is encouraged to consult an appropriate technical reference such as Groundwater and Wells by F. G. Driscoll (1986) for these installation techniques.

Installation

The following procedure installs piezometers at the Lower Clear Creek site using a backhoe and is illustrated in Figure 6.1. The procedure assumes pits will be excavated on the floodplain by a backhoe, that the piezometers will be set in these pits, and the pits will be backfilled by the backhoe with the same excavated materials. Because the lowest groundwater elevations occur during the late summer months, the piezometers should be installed during this time to ensure the groundwater elevation does not drop below the depth of the piezometer (resulting in a dry well).

Instruct the backhoe contractor to excavate a pit in the desired monitoring location. The pit should extend below the summer groundwater table, which is located where water begins to flow freely into the bottom of the excavation. Stop the excavation when the depth of the pit is at least two feet below the surface of the late summer water table.

Next, assemble the PVC pipe according to the depth of the pit and the depth to groundwater. Thread the solid casing into the well screen (slotted casing), thread (or cap) the plug into the bottom of the screen, and stand the assembly vertically in the pit, alongside one of the pit walls (it does not necessarily need to be placed directly in the center of the pit). Set the assembled well in the pit such that approximately 2 to 3 feet of well screen sits *below* the lowest expected groundwater table elevation. In addition, no more than 1 foot of solid casing should remain sticking up above the ground surface. Once the well is sitting in the pit and meets this criteria, have the backhoe operator carefully backfill the pit so that large gravels and cobbles do not damage the screen or solid casing. It will be necessary to hold the piezometer vertically in place with a rod as the pit is backfilled. Continue to backfill until the original ground surface is reached.

Well development

After the well is installed, it needs to be "developed". This process is necessary because excavating and backfilling the pit disturbs the native ground and sets fine sediments into suspension, which can enter the well and/or clog the screen. Developing the well consists of removing water from the well immediately after it is set to draw the turbid water and surrounding fine sediments into the well so that they can be removed. To do this, use either a portable pump or a hand bailer. A hand bailer is an instrument used to collect groundwater from a well. The hand bailer is usually a cylinder, 1 to 2 feet long with a diameter that allows it to slide inside the monitoring well, and contains a check valve at its base.

Development for drinking water wells is considered complete when the water being removed from the well clears of turbidity (Driscoll, 1986). However, clear water may not be an achievable condition following the backhoe installation method (i.e., a large area of disturbance relative to the diameter of the well). Because of this, and because these wells will not serve as a drinking water source, the following well development method is suggested.

To develop the well with a bailer, tie string to the top of the bailer and lower it into the well. As the bailer sinks, it will fill with water. After it fills, remove the bailer from the well (the check valve will keep the water from flowing out). Empty the first bailer into a glass jar, cap the jar, and set it aside, then proceed with developing the well by removing 3 well volumes of water (approximately 5 gallons for a 10 foot deep, 2 inch-diameter well). When the final bailer of water is removed, empty it into a second glass jar. Compare the sediment content of both jars. If the water is significantly less turbid than the initial sample, development can be considered complete. If there is no appreciable decrease in turbidity, repeat the process by

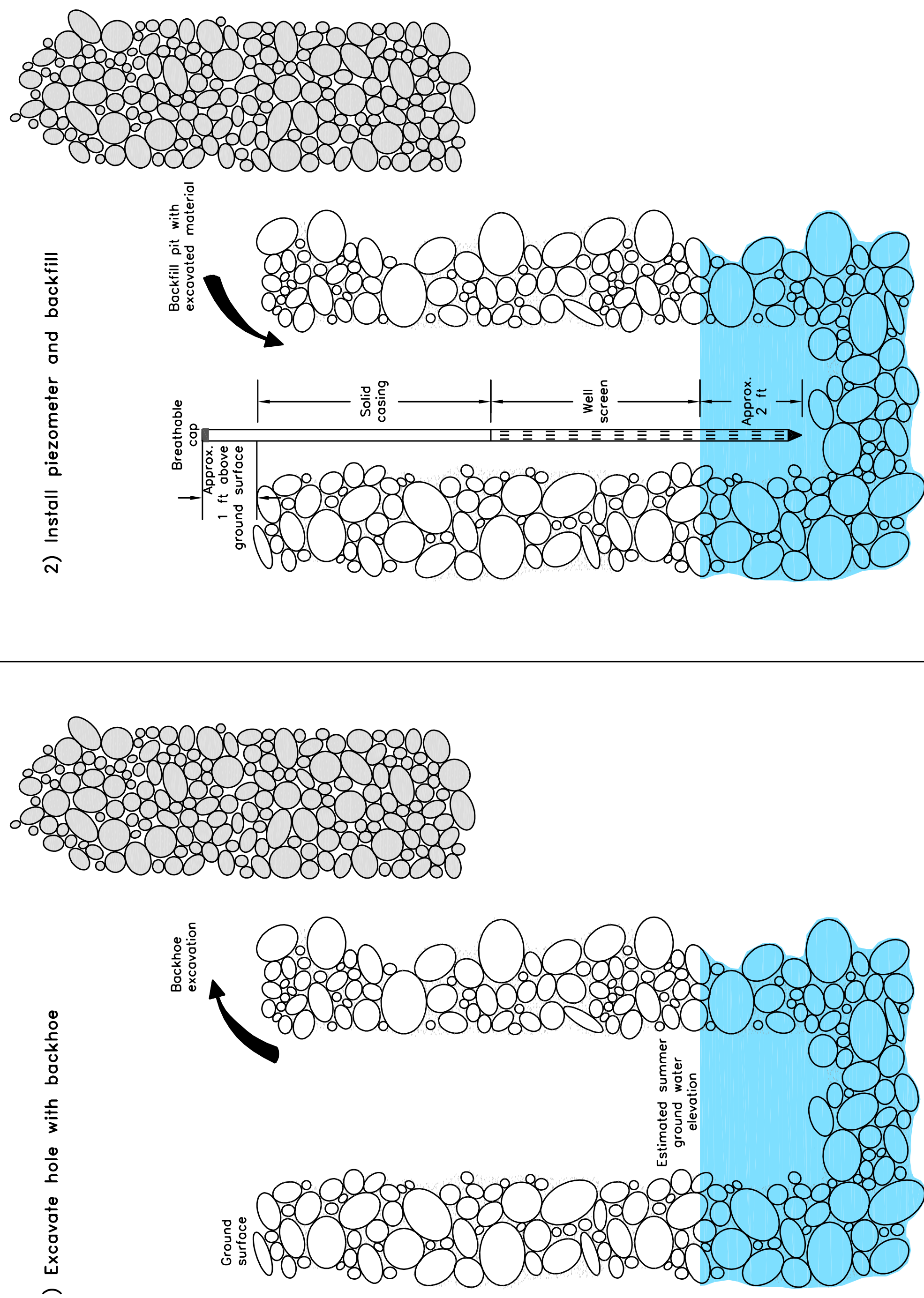

Figure 6.1: Piezometer installation procedure.

removing an additional 3 well volumes of water. If there is still no change, then the sediment concentration present in the samples is likely representative of the sediment concentration of groundwater in the vicinity of the well, and the well can be considered developed (to develop the well with a portable pump, follow the same instructions). Record all measurements and observations in the field notebook.

After development is complete, measure the depth of the inside of the well from the top of the casing. Some sediment will unavoidably be present in the bottom of the well, and this depth to the top of the sediment should be recorded. Next, make a notch on the top of the well casing on its north side. Using a hacksaw or similar device, cut a small (0.5 cm) "v" notch into the well casing, and survey the casing elevation at the notch. This notch will represent a measuring reference point that will serve as the location from which all water level measurements are read and groundwater elevations calculated. To avoid any confusion by other monitoring personnel, label the well with a sharpie, both on the inside rim of the well casing and on the inside of the well cap.

Monitoring

All wells should be measured (or "read") every month to document the temporal groundwater fluctuations at each site. To do this, measure the depth to water in each well using either an electronic water meter, a tape measure, or a stadia rod. If using a tape measure or stadia rod, it is helpful to shine a flashlight down the well to note exactly when the water surface is contacted. The depth to water in each well should always be measured from its "v" notch. Water depths are recorded either in the field notebook or on a special field data form that converts depth-to-water measurements to true elevations. A field data form for recording and converting these measurements is included with the CD that accompanies this appendix. The advantage of using the field form is that true groundwater elevations are instantly available on-site.

In addition, one well per site should be selected for continuous monitoring. To do this, install a "down hole" pressure transducer and data logger to record groundwater elevations on a daily basis. The data collected by the data logger will provide an accurate account of groundwater fluctuations at the site and will supplement the measurements taken at the other wells. The data logger and monitoring assembly should be weatherproof, and a locking well cap should be used to prevent tampering with the equipment. There are several manufacturers of monitoring equipment, such as Global Water Instrumentation, Inc (http://www.globalw.com), who specialize in equipment made for these applications (e.g., Global Water model WL15).

Periodically, the total depth of the inside of each well should be re-measured to determine if there is any significant sedimentation inside the well. Because the piezometer is set in the ground without a filter pack[1], sediment may accumulate in the well over time and the well may need to be re-developed to remove excess fine sediment and clear the well screen.

A filter pack consists of sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of a well between the borehole wall and the well screen to prevent formation material from entering the screen (Driscoll 1986).

7.0 SURFACE SEDIMENTS MAPPING AND SAMPLING

To quantify surface particle size at a monitoring site, a sample of the streambed or floodplain substrate is collected and the distribution of particle size measured by number (e.g., pebble count) or by weight (e.g., sieve analysis). The pebble count technique is best suited for documenting particle size distributions of gravels and cobble substrates typically found within the bankfull channel, and is one of the most common due to its relative simplicity. The pebble count technique is discussed in detail in RM-245. Monitoring personnel should be familiar with the pebble count technique to document size parameters of surface sediment populations.

The channelbed surface within the bankfull channel often contains a mosaic of coarse substrates. For example, a Clear Creek meander bend may contain large cobbles in the riffles, and gravels and cobbles on point bars. Outside the bankfull channel, the floodplain would likely eventually be composed of sand and silt deposited by high flows. In this case, the channel and floodplains may each have separate distinct textural populations, or facies. Because each facies will yield its own unique particle size distribution, each must be sampled separately in order to document representative particle size information.

Materials

The following materials are required to delineate and document textural facies at lower Clear Creek monitoring sites:

- large-scale map or aerial photographs of the monitoring site; for example, a 1” = 25’ scale map is recommended for in-channel mapping and a 1” = 50’ scale map is recommended for floodplain mapping
- clipboard or map board (FS #51035)
- pencils and erasers
- long, flexible measuring tape (commonly 300’ long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- “Rite in the Rain” brand field notebook (FS #49326)
- ruler (metric scale) (FS #47450)
- Total Station (optional)

Technique

To collect representative particle size information at a monitoring site, textural facies must be first delineated and then mapped. Following this task, each facies can be sampled and its particle sizes measured.

To delineate the textural facies at a site, Lisle and Madej (1992) suggest stratifying the bed into recognizable areas whose bed surface grain size composition falls into certain predetermined grain size ranges. Develop the grain size ranges to represent those that make up the bed surface at the site, then delineate facies boundaries based on a visual estimate of a large size parameter. For example, Lisle and Madej (1992) used the D_{75} (particle size in a cumulative distribution for which 75 percent is finer) as a large size parameter to delineate four facies:

Size Range	Facies Description
D_{75} > 64 mm	Cobble
64 mm > D_{75} > 22 mm	Coarse pebble
D_{75} < 22 mm	Fine pebble
Surface covered with > 25% sand	Sand

The above table shows an example of how facies can be delineated at a site, and can be used for in-channel and floodplain mapping. In addition to the above-listed size ranges, a silt size range is recommended for Clear Creek project sites (e.g., surface covered with > 25% silt = silt facies). Because particle size distributions are site-specific, facies size ranges and reference size parameters should be developed for each site.

Once facies are delineated, they should be mapped. Depending on the particular objectives at each site, mapping can rage from a hand-drawn sketch map to a Total Station survey. Hand-drawn sketch maps are typically sufficient to document facies locations, and should be constructed by drawing facies borders on a scaled topographic map, survey-controlled base map, or enlarged orthorectified aerial photograph of the site. A tape strung across a cross section is helpful for locating position on a bar or floodplain, and mapping should focus on plotting facies contacts (with facies labeled). Figure 7.1 presents a sample facies map.

Monitoring

In addition to aiding in the collection of representative bed samples due to textural variation at a site, surface sediments mapping provides a means to document textural evolution at that site (e.g., bed coarsening or fining, silt deposition on floodplains). Moreover, repeated mapping compliments other work performed and can aid in interpreting geomorphic processes at that site. A specific pebble count technique is presented in RM-245 on page 49, and a particle size analysis template for both pebble counts and volumetric bulk samples is included on the CD that accompanies this appendix.

Surface sediments mapping should follow any high flow event capable of causing geomorphic change at a site, or at least on an annual basis. In the case of in-channel monitoring, a monitoring trigger may be a flow exceeding a bed mobility threshold (perhaps 2,000 to 3,000 cfs), whereas on a floodplain, a monitoring threshold may be overbank flows (exceeding 3,000 cfs). Because each facies has its own unique particle size distribution, facies should be recognized (and mapped) prior to conducting pebble counts so that representative areas will be sampled and correct particle size parameters documented.

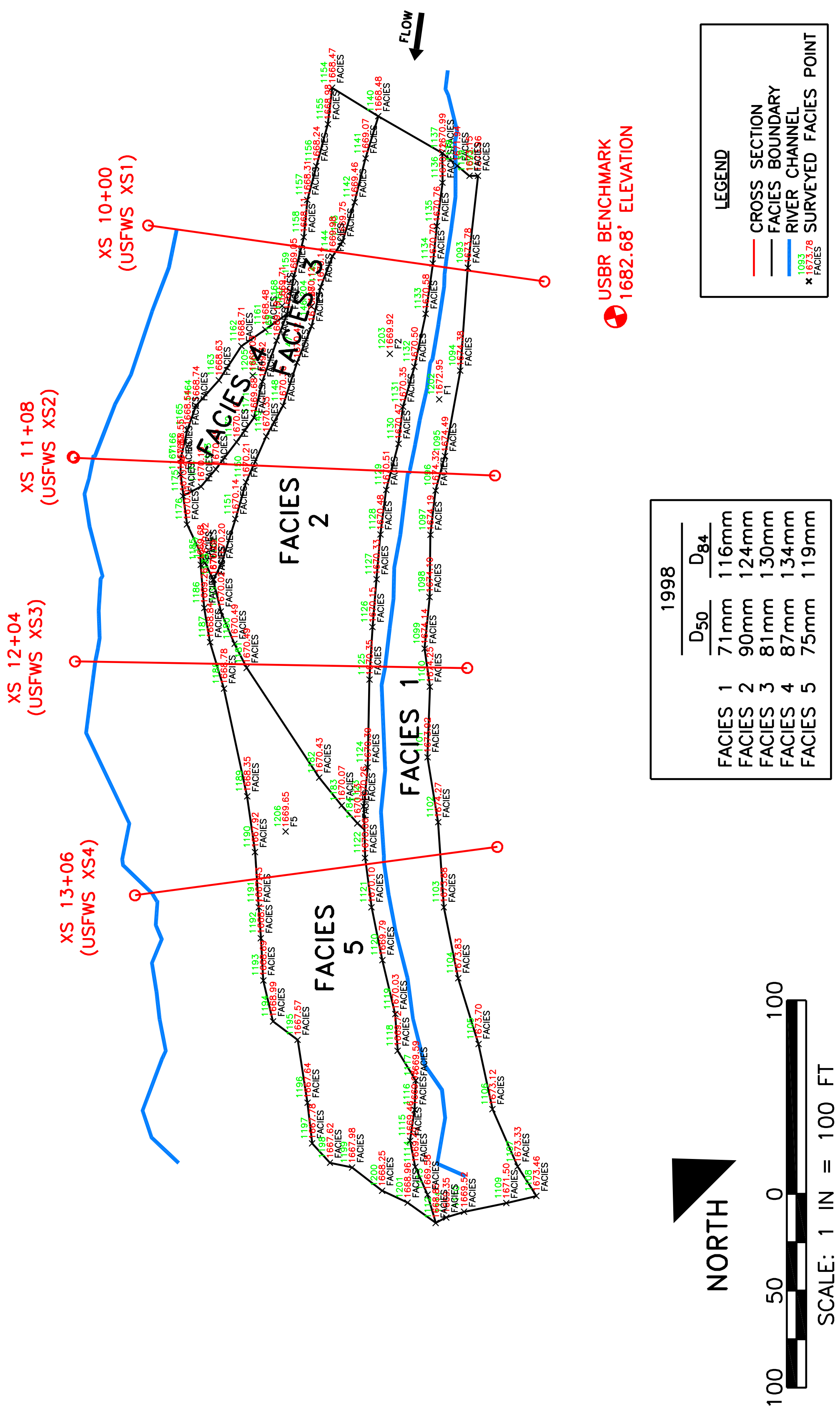

Figure 7.1: Sample textural facies map from the Trinity River, created by a total station survey.

8.0 MARKED ROCKS

Marked rocks, or tracer rocks, are used to document channelbed surface mobility on alluvial features (e.g., point bars, medial bars, pool tails, etc.). Specific particle size classes representative of the area to be monitored are painted a bright color, such as fluorescent orange, and placed at discrete locations in the channel along a monitoring cross section. Following a discrete high flow, the cross section is revisited to document whether mobility of the marked rocks occurred, and if so, how far they moved. The marked rocks are then re-set or replaced as initially installed for the next high flow event. In addition, marked rocks should be also set at a "control" cross section, located upstream of a restoration site, to compare and contrast bed mobility thresholds between unrestored channel areas and restoration sites.

Materials

The following materials are required to set and monitor marked rocks for channelbed surface mobility on alluvial features:

- bright paint, at least 3 cans of spray paint (e.g., Krylon brand "invert-a-can" or 1 quart of canned paint per cross section
- disposable paint brushes (if using canned paint)
- "sharpie" brand waterproof marker for labeling rocks
- tarp for painting rocks
- long, flexible measuring tape with clips or similar fasteners to affix tape to cross section rebar pins (FS #39532 or #39851)
- "Rite in the Rain" brand field notebook (FS #49326)
- particle size distributions from a pebble count or sieve analysis at the monitoring cross section
- waders and wading boots

Installation

Marked rocks should be grouped into "sets", with each set consisting of a D_{84}, D_{50}, and D_{31} (particle sizes in a cumulative distribution for which 84, 50, and 31 percent is finer, respectively). The size of the D_{84}, D_{50}, and D_{31} for each facies are based on the results of a pebble count or other sediment sampling technique as described in Section 7.0. First, collect rocks from a nearby exposed bar that represent each size class. Collect enough rocks so that sets can be placed on a cross section at three-foot intervals along the bankfull width (i.e., if the width of an exposed point bar on the cross section is 60 feet, collect 20 rocks each of the D_{84}, D_{50}, and D_{31} size class).

It is common for the monitoring cross section to pass through more than one facies due to particle sorting during high flows. If these conditions exist, it is best to split the marked rock sets into no more than two separate populations according to the major facies changes.

Once the rocks are collected, group them by size class and place them on the tarp to air dry (if needed), making sure their surfaces are clean and free of any fine sediment. This procedure works best when performed on a hot summer day. After the rocks have dried, paint one side, allow to dry, flip the rocks over, and paint the other side. After the paint has dried, use a thick "sharpie" brand waterproof marker to label each rock set. Label each rock set with a sequential letter or number, identify which lateral tape station on the cross section upon which it was originally placed, and record this data in the field notebook or data form. Each cross section should have its own unique marked rock-labeling scheme, such as numbers, letters, and/or paint color (see Figure 8.1).

Next, string the long tape tight across the cross section in the same manner as if the cross section was to be surveyed (affix the zero end of the tape to the left bank rebar pin and pull the tape tight across the stream). Begin placing rock sets by starting at one end of the bankfull channel, placing rock sets at two-foot intervals: place the D_{84} on the cross section, the D_{50} one foot upstream of the D_{84}, and the D_{31} one foot upstream of the D_{50} (Figure 8.1). This placement scheme prevents artificial shielding of smaller tracers by larger tracers. Each marked rock should rest on the bed surface so that its exposure mimics that of the surrounding rocks. To do this, place each marked rock on the bed surface by removing a similar sized rock from the bed and setting the marked rock in its place. This allows marked rock placements to reasonably maintain natural bed surface conditions and avoid unnaturally over-exposing or under-exposing the marked rocks. Record the precise station each mark rock set is located in the fieldbook.

Monitoring

The primary monitoring objectives are to determine at what streamflow discharge the marked rocks move, which alluvial features are mobilized, where rocks move on each feature, and how far the rocks move. Because the D_{84} at the Clear Creek project sites is designed to move at flows slightly less than the bankfull discharge (3,000 cfs), marked rocks should be checked for movement following flows greater than 2,000 cfs. Past studies using marked rocks suggest that after its initial placement, the rock sometimes reorients itself to a more hydraulically stable location rather than being truly mobilized (McBain and Trush 1997). Therefore, a marked rock should not be considered “mobilized” if its travel distance does not exceed two feet from its initial set position.

To record movement after a high flow, string the tape between cross section rebar pins and note whether each marked rock set was mobilized, and measure how far downstream they traveled. Next, inventory which rocks are missing. If they can be found downstream and have adequate paint and labeling, replace them on the cross section for the next monitoring event. However, many marked rocks that move downstream cannot be recovered due to substantial distance mobilized downstream, burial, and/or paint abrasion. New rocks of the appropriate size class must be gathered, dried, re-painted and labeled, and set on the cross section to await the next transporting flow. Record in the field book which rocks moved from the cross section and which were replaced. A marked rock data form is included on the CD that accompanies this appendix.

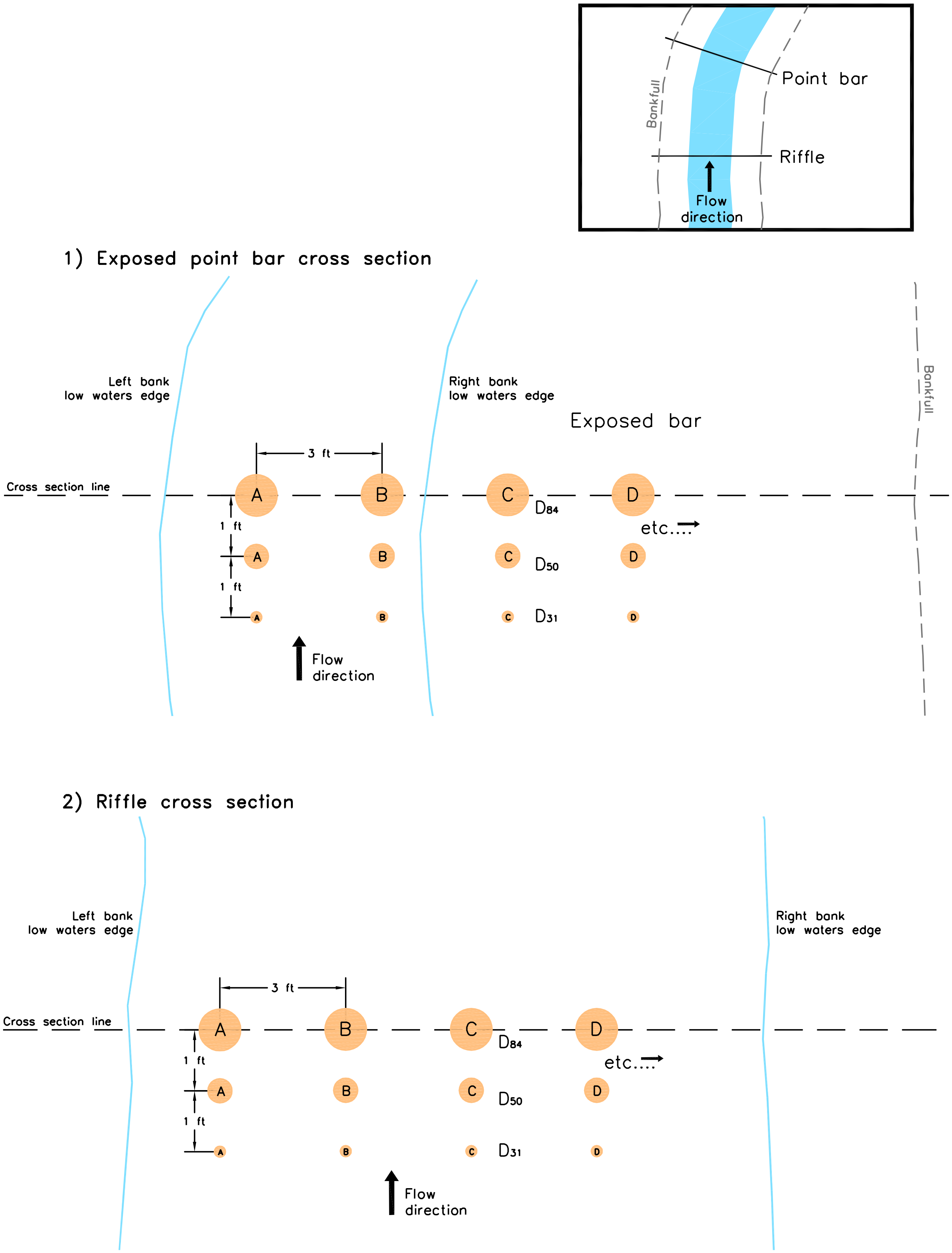

Figure 8.1. Typical tracer gravel placement along a cross section through hypothetical point bar(1) and riffle (2)

9.0 SCOUR CORES

Scour cores are used to document channelbed scour and redeposition on alluvial features (e.g., point bars, medial bars, riffles, pool tails). To measure this, a core of channel bed substrate is removed and backfilled with brightly painted, uniform size "tracer gravels" that are slightly smaller than the surrounding bed materials. When discharge increases and scours the surrounding bed, the tracer gravels also become entrained and are transported downstream. Following high flows capable of causing scour and redeposition, the scour core location is revisited to document scour and redeposition depths. Two to three scour cores are typically installed at a site where scour and redeposition is to be measured.

Materials

The following materials are required to install and monitor scour cores (note that the following materials list is for one scour core only):

- McNeil-type sampler, 6", 8", or 12" diameter (depending on size of substrate), 18" to 24" deep (see Figure 9.1)
- pre-painted tracer gravels approximating the D_{31} size class (enough to backfill the volume of the McNeil sampler); this size is required to ensure complete tracer gravel mobilization when the surrounding bed scours. For Clear Creek, small gravels finer than 1 inch should work.
- survey equipment (engineer's level, tripod, stadia rod, field notebook) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape with clips or similar fasteners to affix tape to cross section rebar pins (FS #39532 or #39851)
- waders and wading boots
- neoprene gloves
- small hand tools (e.g., gardening trowel) to excavate the substrate
- plastic 5-gallon bucket
- "Rite in the Rain" brand field notebook (FS #49326)

Installation

Choose a location to measure scour. Scour cores are commonly placed on a cross section to provide precise stationing and easiest to install on exposed bars. Survey the elevation of the bed surface (referenced to the site primary benchmark) and record this elevation in the field notes. Next, manually work the McNeil sampler approximately 1.5 feet into the bed, and place the excavated substrate in the 5-gallon bucket for disposal away from the scour core. This process can be tedious; best results are obtained by iterations of working the sampler a few inches into the bed, excavating some substrate, and repeating the process until the excavation is roughly 1.5 feet deep. Once the target depth is reached, survey the elevation of the bottom of the core, then backfill the core to roughly the original bed elevation with the tracer gravels. After backfilling the core, remove the McNeil sampler, smooth the surface of the tracer gravels with your hand, and survey the elevation of the top of the tracer gravels (see Figure 9.1, steps 1 through 5, and Figure 9.2).

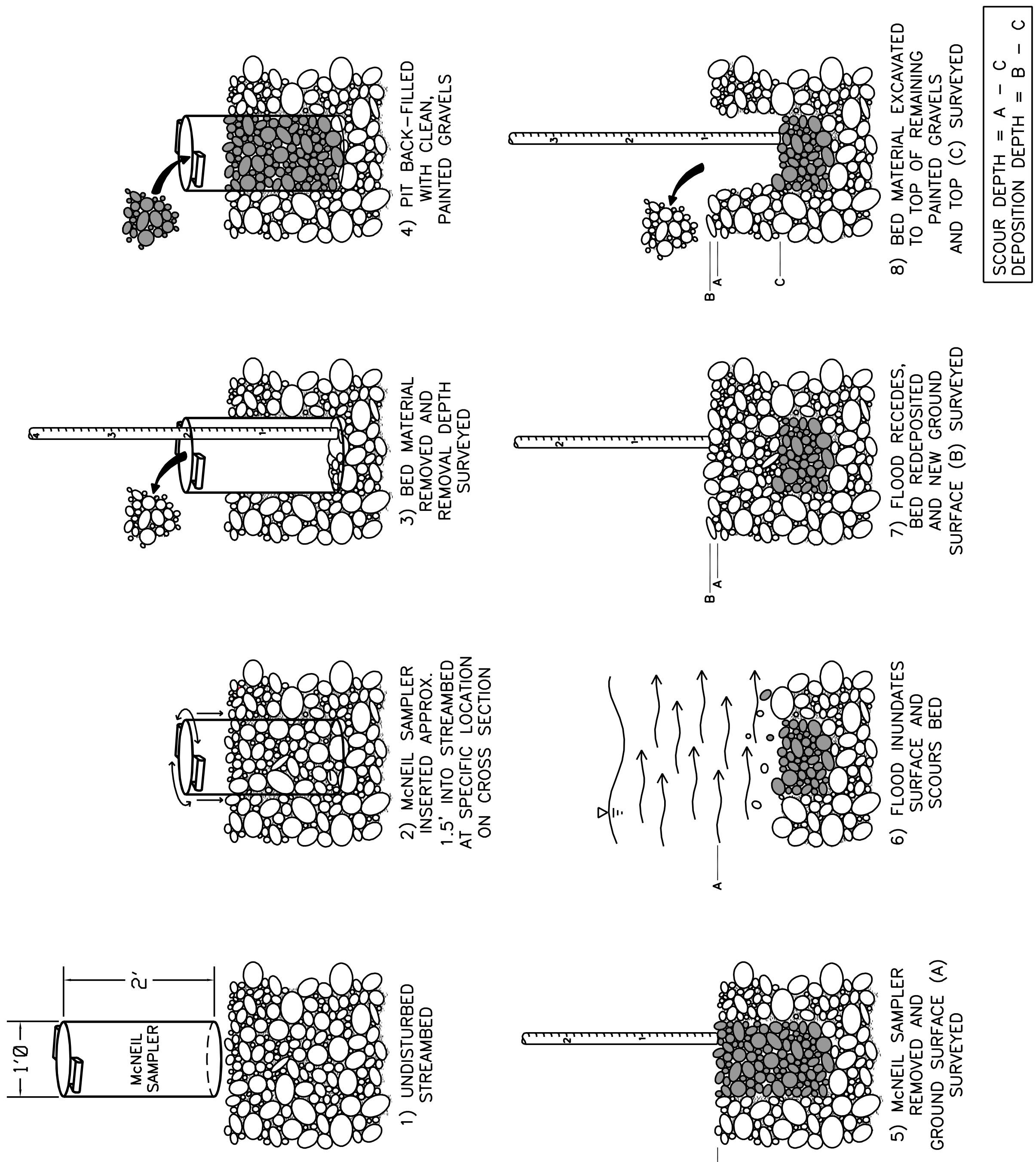

Figure 9.1: Scour core installation and monitoring procedure.

Figure 9.2: Photograph of freshly installed scour cores (yellow tracer gravels are exposed on the bed surface) on the Trinity River. A long tape is stretched perpendicular across the channel, and blue flagging is tied to the tape delineating precise scour core stationing. Note that there are 5 scour cores visible in the photograph; Clear Creek sites should only contain 2 or 3 on each cross section due to its smaller channel dimension.

<u>*Monitoring*</u>

During a high flow event that scours the bed, the tracer gravels will became entrained and transported away from the scour core. To document scour and redeposition depths following a scouring event, reoccupy the scour core location by stringing the tape across the cross section. Once the tape is strung, locate the precise station the core was installed, and survey the bed surface elevation. Using the McNeil sampler, carefully re-excavate the core until the tops of the tracer gravels are found It is important to re-excavate slowly, so the surface of the tracer gravels is not disturbed; if the excavation extends into the tracer gravels, an inaccurately large scour and redeposition depth will be recorded. Once the surface of the tracer gravels is exposed, survey the elevation of the top of the tracer gravels. Differences in surveyed bed elevations and surface tracer gravel elevations document scour and redeposition depths (Figure 9.1, steps 6 through 8). A scour core installation and excavation form is included on the CD that accompanies this appendix.

10.0 STAFF GAGE

Staff gages are used to measure the river's water surface elevation (stage) and are commonly associated with stream gaging stations to establishing stage-discharge relationships. However, staff plates can be installed independent of gaging stations for visual stage observations (to correlate to discharge) at any location of interest.

Materials

The following materials are required to install a single staff gage:

- enameled steel staff plate, marked in feet and tenths (FS #39732)
- 3 inch "channel iron", 7 feet long, with one end cut at a 45° angle (see Figure 10.1)
- custom-made 3-inch channel iron pounder (similar in design to a standard metal fence post pounder)
- economy heartwood redwood 2x4, ripped to fit snugly into channel iron and provide a flush surface to mount the staff plate (see Figure 10.1)
- survey equipment (engineer's level, tripod, stadia rod) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- "Rite in the Rain" brand field notebook (FS #49326)
- stainless steel carriage bolts and wood screws
- drill with 3/8" bit for mounting holes in channel iron and redwood

Installation

Choose a location to install the staff gage. The staff gage should be located in low-velocity water and out of the path of debris, and should also be located in a position that can record the lowest anticipated stage in the channel (Harrelson et al. 1994). If possible, the staff gage should also be installed in a location where the riffle crest that controls the low flow water surface elevation is fairly stable.

After a suitable location is selected, install the channel iron approximately 3 feet vertically into the substrate such that the wood and staff plate can be affixed after the iron is set into the bed, keeping in mind that the staff gage will be read from the bank (i.e., be sure that the staff plate will face the bank from which stage will be observed and recorded). Next, drill four 3/8" diameter holes in the upper 3-½' of channel iron and redwood, and use stainless steel carriage bolts to attach the wood to the channel iron. Then use stainless steel wood screws to attach the staff plates to the redwood (see Figure 10.1). When affixing the staff plates to the wood, be sure that the plates are positioned low enough so that they will record stage at the lowest anticipated flow in the channel.

After the staff gage is set, survey the elevation of the top of the staff plate (the 3.33' or 6.66' elevation) to establish the real elevation of the staff plate by surveying from the primary site benchmark. This will establish a real elevation of the staff plate and thereby establishing a datum to convert all stage readings to real elevation if needed. Establishing the elevation of the staff gage also provides control in case the staff gage is damaged or disturbed. In addition, it may be necessary to set more than one staff gage in order to cover the expected range of flows at the site (i.e., if stage varies more than 3.33' over the range of flows of

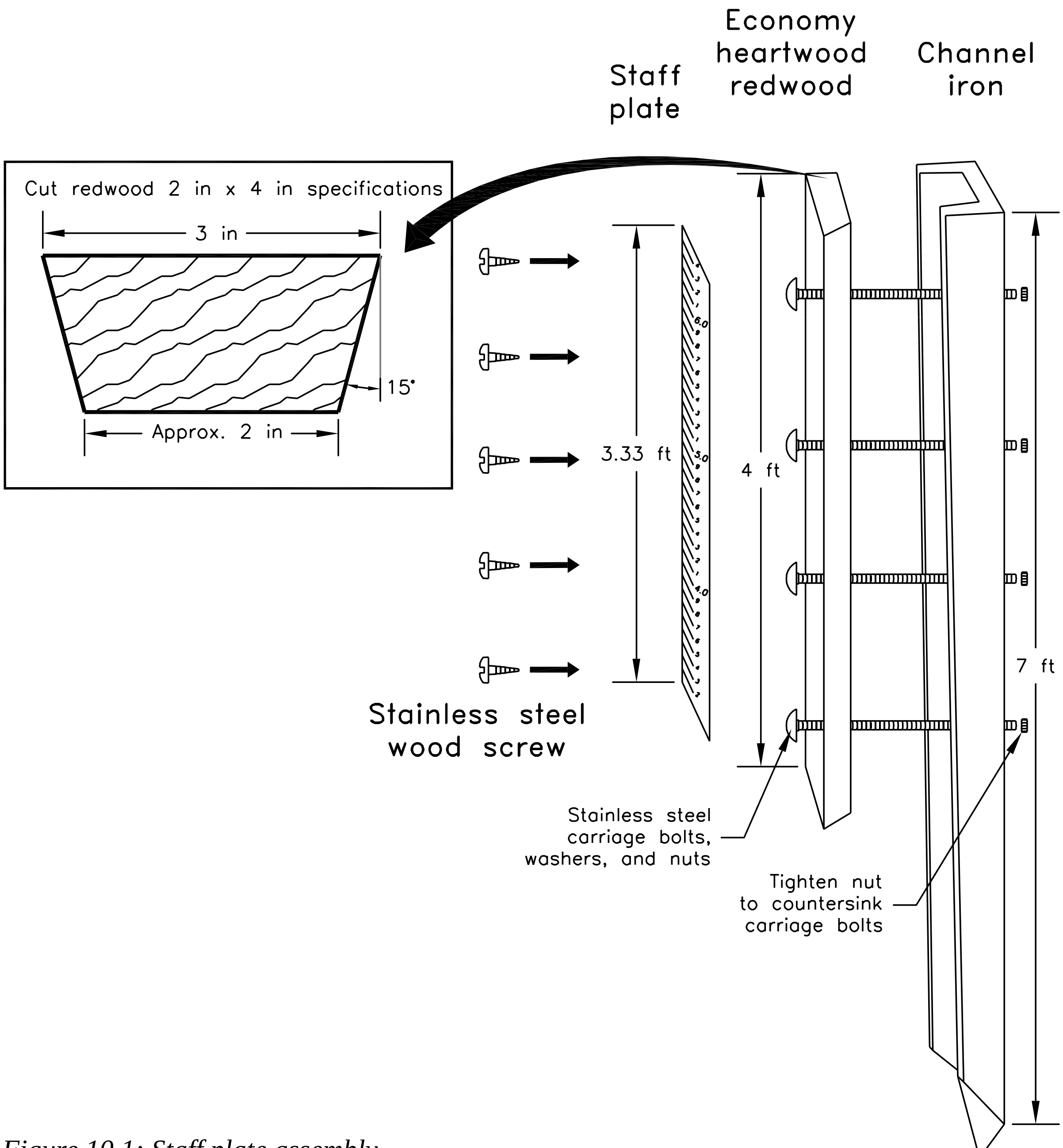

Figure 10.1: Staff plate assembly

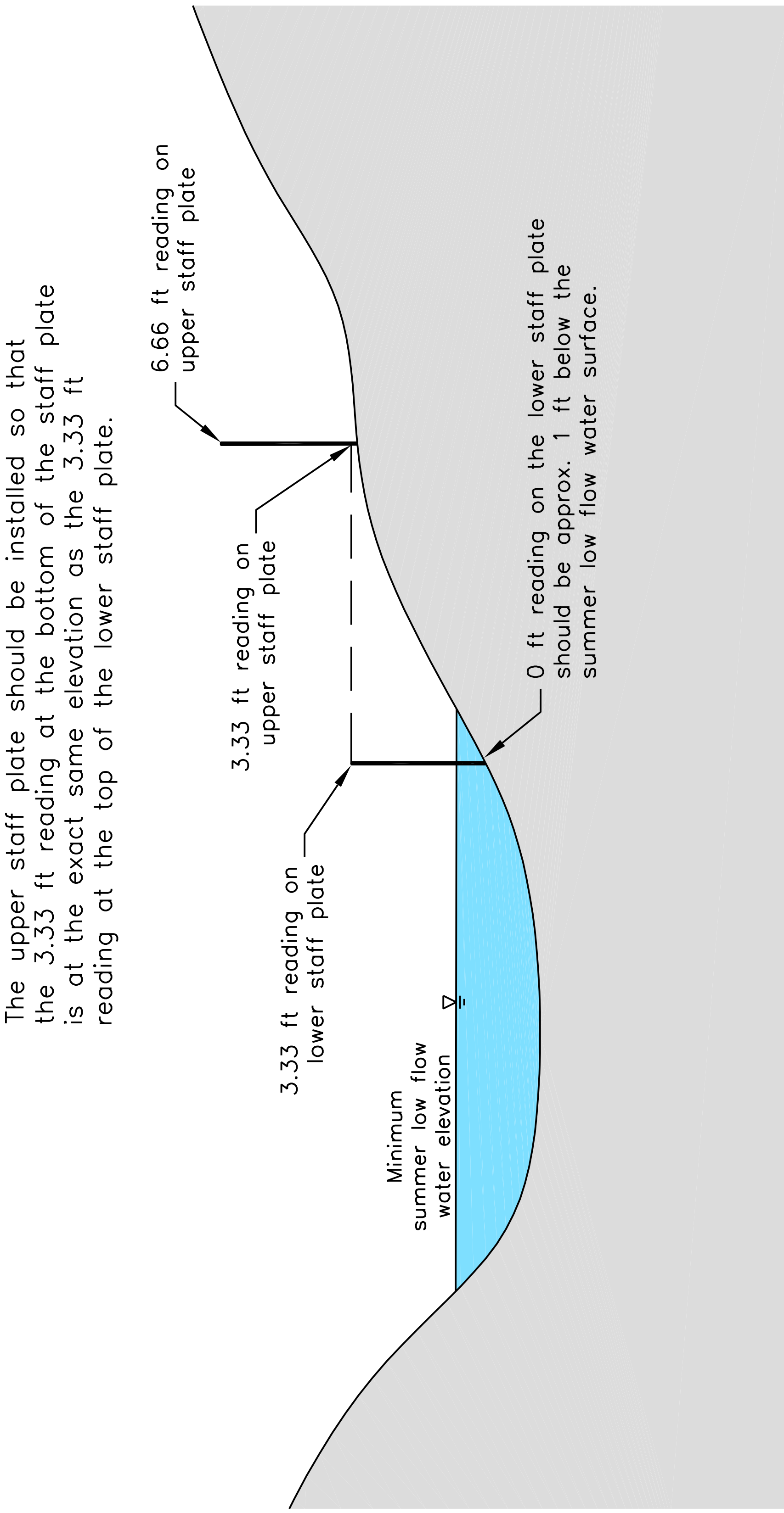

Figure 10.2: Multiple staff plate placement schematic

interest). In this case, it is important to set the second staff plate using survey control so that the elevation of the 3.33' line on the top of the lower staff plate is the same elevation as the 3.33' line on the bottom of the upper staff plate (see Figure 10.2).

Monitoring

The water surface should be read from the staff gage whenever the site is visited. This reading is commonly referred to as "gage height". Gage height and time of the reading should be recorded in the field notes.

Because the fundamental purpose of the staff gage is to correlate stage to discharge, should be measured at the time the staff gage is installed and at later times during various stages. Moreover, discharge must always be measured near the staff gage, whether at the location of the staff gage or at a location up- or downstream (as long as discharge is neither gained or lost between where discharge is measured and the staff gage). Generally, the closer the discharge is measured to the observed stage, the better.

When total discharge for a cross section is computed, its value is plotted against the gage height. Successive measurements of stage and discharge are plotted on what is called a discharge rating curve (Leopold 1994). On log-log graph paper, plot the gage height on the ordinate (Y-axis) and the discharge on the abscissa (X-axis) (Harrelson et al. 1994). An example rating curve is presented as Figure 10.3.

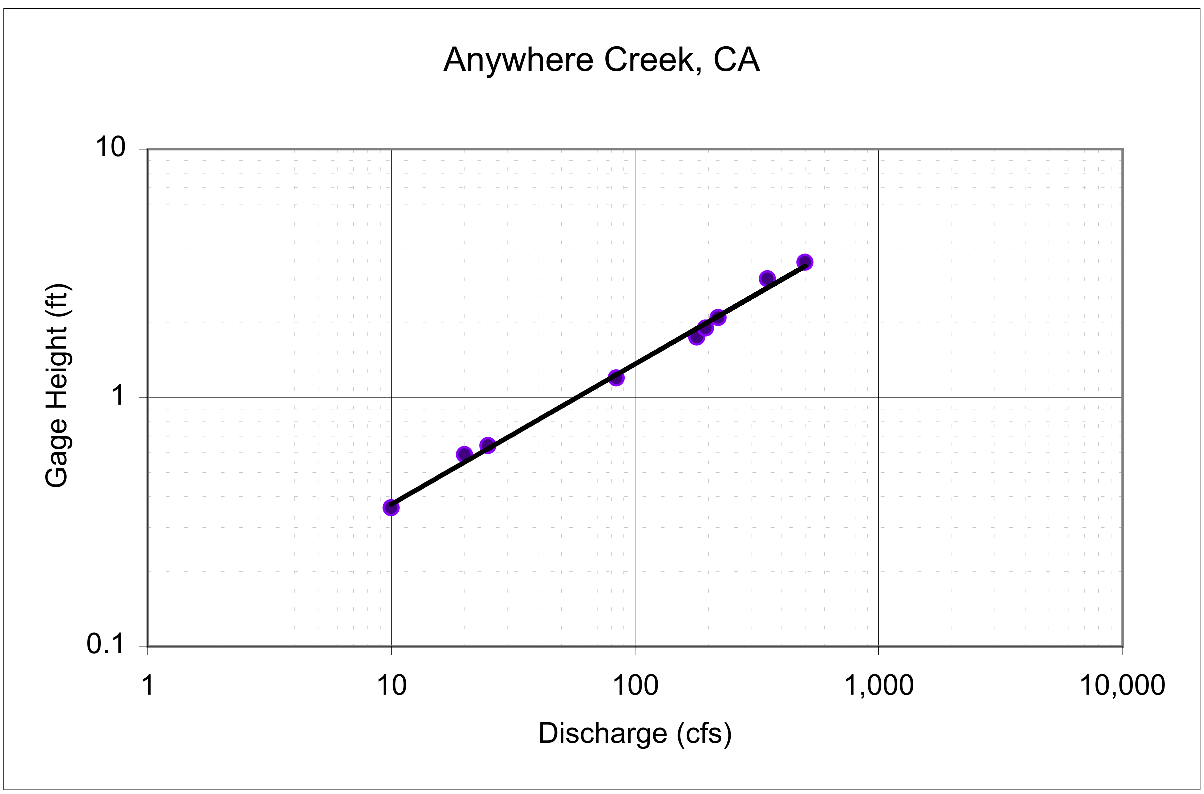

Figure 10.4. Example rating curve showing a power function fit of measured gage heights and discharges.

The goal of placing staff plates is to develop a stage-discharge rating curve for the location where the plate is set, upon which we can evaluate flow-stage relationships important for project performance (i.e., do the constructed flood plains inundate at 3000 cfs?). Because several staff gages have already been installed at Clear Creek project sites, (see figures 4.2 and 4.3) it would be impractical to take a discharge measurement at every staff gage to develop the rating curves. Instead, a single discharge measurement approximately halfway between the two Clear Creek project sites (Reading Bar and Restoration Grove) is sufficient to plot against stage recorded at all staff gages. The recommended location for this discharge measurement location is at Renshaw Riffle (river mile 5.3) and assumes that this measurement at Renshaw Riffle accurately depicts discharge at both project sites.

To accurately document stage-discharge relationships for a measured discharge at Renshaw Riffle to water stage recorded at each staff gage, we recommend first taking a discharge measurement, then immediately collecting staff plate readings at all staff gages. Alternatively, if discharge cannot be measured at Renshaw Riffle, discharge can be obtained from the U.S. Geological Survey Clear creek near Igo, CA gage (Gage ID# 11372000). However, because the Igo gage is located further from the project sites than the Renshaw Riffle, stage-discharge relationships will not be as representative of local site conditions if there is a tributary derived runoff event occurring. In addition, the discharge recorded at Igo will be different than discharge measured at Renshaw Riffle. If discharge data is used from both sources (Renshaw Riffle and Igo), the stage-discharge data can be plotted on the same graph, but each discharge source should have its own data point symbol. The Igo data points should be closely scrutinized to see if they can be reasonably used in developing rating curves at staff plates in the project reach.

Because the channel geometry can change where discharge is measured (thereby affecting the area-velocity relationship for discharge computation), the relationship between stage and discharge can change. Changes in the stage-discharge relationship will cause subsequent stage-discharge points to deviate from the rating curve. This is called a “shift” in the rating. After such a change takes place, such as after a large flood, a new rating curve will have to be constructed via a new series of discharge measurements and staff gage readings.

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